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## RESEARCH MEMORANDUM

SOME MEASUREMENTS OF THE BUFFET REGION OF A SWEEP-WING  
RESEARCH AIRPLANE DURING FLIGHTS TO  
SUPERSONIC MACH NUMBERS

By Thomas F. Baker

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NATIONAL ADVISORY COMMITTEE  
FOR AERONAUTICS

WASHINGTON

May 28, 1953

MTLAL-4143

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## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SOME MEASUREMENTS OF THE BUFFET REGION OF A SWEEP-WING  
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## SUMMARY

Measurements of the intensity of buffeting experienced by the Douglas D-558-II research airplane have been made in the Mach number range from 0.85 to about 1.10. The values of airplane normal-force coefficient attained varied from about 1.0 at a Mach number of approximately 0.9 to above 1.5 at a Mach number of approximately 1.06.

Buffeting was encountered by the D-558-II airplane at both subsonic and supersonic Mach numbers. The intensity of the buffeting varied with Mach number and with airplane normal-force coefficient, but, regardless of Mach number, only low-intensity buffeting was experienced at values of airplane normal-force coefficient less than 0.4. High-intensity buffeting was not encountered at Mach numbers greater than about 0.925 nor at normal-force coefficients less than 0.65. The absence of high-intensity buffeting during the maneuvers to high lift at supersonic speed indicates that no maneuverability restrictions, insofar as buffeting is concerned, will be necessary for similar airplanes during supersonic flight. The significant buffet frequencies, as regards amplitude and occurrence, corresponded to the first modes of symmetrical wing bending and wing torsion.

## INTRODUCTION

Buffeting may be defined as an aerodynamically induced structural vibration of one or more components of an airplane. The origin of buffeting lies in the fluctuating pressures of unsteady flow associated with separation. Knowledge of the buffeting encountered by full-scale airplanes at transonic speeds is of interest, since the onset of buffeting at low values of lift can restrict the maneuvering range of the airplane. This paper presents the results of some measurements

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of the buffeting encountered by a swept-wing research airplane during high-altitude flights at high subsonic and supersonic Mach numbers.

The airplane used for this investigation was an air-launched rocket-powered version of the Douglas D-558-II research airplanes which was procured by the Bureau of Aeronautics, Department of the Navy, for use by the National Advisory Committee for Aeronautics as part of the cooperative NACA-Navy transonic flight research program. During exploratory flights performed primarily to demonstrate the operational characteristics of the airplane, data were obtained on lateral stability, longitudinal trim, and buffeting characteristics.

#### SYMBOLS

$a$	velocity of sound, ft/sec
$C_{N_A}$	airplane normal-force coefficient, $nW/qS$
$g$	acceleration due to gravity, ft/sec <sup>2</sup>
$h_p$	pressure altitude, ft
$M$	Mach number, $V/a$
$n$	airplane normal load factor, g units
$q$	free-stream dynamic pressure, $\frac{1}{2}\rho V^2$ , lb/sq ft
$S$	wing area, sq ft
$V$	free-stream velocity, ft/sec
$W$	airplane gross weight, lb
$\Delta C_{N_A}$	incremental fluctuation of airplane normal-force coefficient due to buffeting, $W\Delta n/qS$
$\Delta n$	incremental fluctuation of load factor due to buffeting, g units
$\rho$	mass density of air, slugs/cu ft

## AIRPLANE AND INSTRUMENTATION

The Douglas D-558-II airplanes have sweptback wing and tail surfaces and were originally designed for combination turbojet and rocket power. The airplane used in the present tests, however, has the turbojet engine removed, has no air inlet or exhaust ducts, and is powered solely with a rocket engine exhausting from the rear of the fuselage. Photographs of the airplane are shown in figure 1 and a three-view drawing is shown in figure 2. Pertinent airplane dimensions and physical characteristics are listed in table I. The airplane is equipped with an adjustable stabilizer and both leading-edge slats and stall-control fences are incorporated on the wing. The wing slats can be locked in the closed position or can be unlocked.

Standard NACA recording instruments, synchronized by a common timer, were used to measure all quantities pertinent to this investigation. The airspeed system was calibrated at all Mach numbers by the NACA radar phototherodolite method (ref. 1). The accuracy of the Mach numbers presented herein is estimated to be  $\pm 0.025$ .

## TESTS AND PROCEDURE

The data presented in this paper were obtained at altitudes varying from 30,000 to 63,000 feet in the Mach number range from 0.85 to 1.2. The Reynolds number varied from  $6 \times 10^6$  to  $21 \times 10^6$ . The data were taken with the airplane in the clean (slats-locked-closed) condition during rocket-powered climbs and during turns and pull-ups performed at high altitudes after the exhaustion of rocket fuel. No significant difference was found between power-on and power-off data that could be attributed to the presence of power.

The intensity of the buffeting was determined by measuring the amplitude of buffet-induced fluctuations in normal acceleration and converting the incremental accelerations to values of incremental normal-force coefficient  $\Delta C_N$ . The accelerometer used for buffet-intensity determination was an air-damped instrument having a natural frequency of 10.5 cycles per second. The response of this instrument varies with air density and with forcing frequency. The incremental acceleration data obtained from it have been corrected for both variants.

## RESULTS AND DISCUSSION

Buffeting was encountered by the Douglas D-558-II airplane in both level flight and maneuvering flight at subsonic and supersonic speeds. Typical variation of the intensity of buffeting experienced during an accelerated climb in the Mach number range from 0.81 to 1.02 is shown in figure 3. It will be noted that variations in airplane normal-force coefficient  $C_{NA}$  were, in general, accompanied by similar variations in buffet intensity. It should be observed, however, that in the Mach number range from about 0.85 to 0.98, the mean level of  $C_{NA}$  continuously decreased; whereas, the level of buffet intensity increased in the Mach number range from 0.85 to 0.91 and did not decrease appreciably until a Mach number of 0.96 was reached. Heavy buffeting and high drag were avoided during accelerated climbs to high altitude by the use of low values of airplane normal-force coefficient at Mach numbers above about 0.88. For comparison with actual flight values, the  $C_{NA}$  necessary for 1 g flight is indicated in the figure. The apparent discontinuity in the curve was caused by a 7,000-foot increase in altitude at essentially a constant Mach number.

As indicated in figure 3, the intensity of buffeting varied with both lift and Mach number. Inasmuch as maneuvers were performed in a power-off condition, constant Mach number data could not be obtained. However, a typical variation of  $\Delta C_N$  with  $C_{NA}$  during two turns, one subsonic and one supersonic, is presented in figure 4 with the approximate Mach numbers at various values of  $C_{NA}$  indicated in the figure. During both maneuvers, an uncontrolled "pitch up" occurred to the peak values of  $C_{NA}$  shown. In the maneuver at subsonic speed (fig. 4(a)) the intensity of the buffeting increased rapidly with lift at values of  $C_{NA}$  greater than 0.55. At supersonic speeds (fig. 4(b)) the increase in buffet intensity with  $C_{NA}$  was very gradual in comparison with the subsonic data but shows that buffeting definitely exists at supersonic Mach numbers. It is interesting to observe that, at a Mach number of about 1.10, a normal-force coefficient of 1.00 is required for buffeting at intensities greater than  $\Delta C_N = \pm 0.02$ ; whereas, in figure 3, buffet intensities on the order of  $\Delta C_N = \pm 0.02$  occurred at a normal-force coefficient of 0.35 at  $M = 0.94$ . The frequencies at which buffet-induced fluctuations in normal acceleration were recorded were 12.5 and 45 cycles per second. These frequencies correspond to the first mode of symmetrical wing bending and the first mode of wing torsion, respectively. As stated in the section entitled "Tests and Procedure," the amplitudes of incremental accelerations were not recorded at true values. A correction based on a forcing frequency of 12.5 cycles per second was applied to the data. Accordingly, the

buffet intensities presented in figures 3 and 4, and those presented subsequently, apply only to the lower of the two buffet frequency levels. It is believed that only small error in the buffet intensities presented has been introduced because of the neglect of the 45-cycle-per-second fluctuations.

The region, in terms of Mach number and airplane normal-force coefficient, in which buffeting was experienced is presented in figure 5. These data were taken during both level and maneuvering flight. Maximum lift, as evidenced by a decrease in lift with increase in angle of attack has not been attained by the airplane. The peak values of  $C_{N_A}$  which have been attained at Mach numbers above 0.8 are the maximum values of  $C_{N_A}$  shown in figure 5. The buffet intensities indicated by the various symbols were measured, in general, every 0.10 second during the time buffeting was experienced. Some points, however, have been omitted for clarity. The upper limits of buffet intensities equivalent to  $\Delta C_N$  values of  $\pm 0.01$ ,  $\pm 0.02$ ,  $\pm 0.03$ , and  $\pm 0.05$  have been drawn about the data insofar as possible, but, in general, at supersonic speeds the data are not sufficient to define the limits of buffeting. No attempt has been made to define either the subsonic or supersonic buffet boundary from these tests, but for all practical purposes, the buffet region of the D-558-II is bounded by the lower limit of buffet intensities greater than  $\Delta C_N = \pm 0.01$ . Low-intensity buffet is regarded as that equivalent to values of  $\Delta C_N$  less than  $\pm 0.02$  and intensities greater than about  $\Delta C_N = \pm 0.05$  is considered high-intensity buffeting. At normal-force coefficients less than 0.4, it can be seen that regardless of Mach number only low-intensity buffeting was experienced. Of some interest is the fact that high-intensity buffeting was not experienced at Mach numbers greater than about 0.925 nor at normal-force coefficients less than 0.65. The absence of high-intensity buffeting within the lift range covered at supersonic speeds indicates that no buffet-created maneuverability restrictions will be required on similar airplanes. Very low-intensity buffeting at values of  $\Delta C_N$  less than  $\pm 0.01$  was found to exist at normal-force coefficients below the buffet region both at subsonic and at supersonic Mach numbers. Neither the existence nor the intensity of this buffeting appeared to vary with Mach number or lift. It was observed to occur intermittently at low lift and subsonic speeds and at both low and moderate values of lift at supersonic speeds up to  $M = 1.85$ , the maximum attained during the investigation. Similar intermittent buffeting of almost negligible amplitude was noted during flights of the Bell X-1 airplane at supersonic speeds.

During previous flight investigations with this airplane, (powered only by a turbojet engine) a buffet boundary, which was defined as the variation with Mach number of the airplane normal-force coefficient at



which buffeting started, was established for Mach numbers up to 0.9 at altitudes varying from 15,000 to 20,000 feet (ref. 2). These data are shown in figure 6 with the buffet region determined in the present tests.

#### CONCLUDING REMARKS

Buffeting was encountered by the Douglas D-558-II airplane at both subsonic and supersonic Mach numbers. The intensity of the buffeting varied with Mach number and with airplane normal-force coefficient, but regardless of Mach number, only low-intensity buffeting was experienced at values of airplane normal-force coefficient less than 0.4. High-intensity buffeting was not encountered at Mach numbers greater than about 0.925 nor at normal-force coefficients less than 0.65. The absence of high-intensity buffeting during the maneuvers to high lift at supersonic speed indicates that no maneuverability restrictions, insofar as buffeting is concerned, will be necessary for similar airplanes during supersonic flight. The significant buffet frequencies, as regards amplitude and occurrence, corresponded to the first mode of symmetrical wing bending and wing torsion.

Langley Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va.

#### REFERENCES

1. Zalovcik, John A.: A Radar Method of Calibrating Airspeed Installations on Airplanes in Maneuvers at High Altitudes and at Transonic and Supersonic Speeds. NACA Rep. 985, 1950. (Supersedes NACA TN 1979.)
2. Mayer, John P., and Valentine, George M.: Flight Measurements With the Douglas D-558-II (BuAero No. 37974) Research Airplane. Measurements of the Buffet Boundary and Peak Airplane Normal-Force Coefficients at Mach Numbers up to 0.90. NACA RM L50E31, 1950.

TABLE I.- PHYSICAL CHARACTERISTICS OF THE  
DOUGLAS D-558-II AIRPLANE

## Wing:

Root airfoil section (normal to 0.30 chord) . . . . .	NACA 63-010
Tip airfoil section (normal to 0.30 chord) . . . . .	NACA 631-012
Total area, sq ft . . . . .	175.0
Span, ft . . . . .	25.0
Mean aerodynamic chord, in. . . . .	87.301
Root chord (parallel to plane of symmetry), in. . . . .	108.51
Tip chord (parallel to plane of symmetry), in. . . . .	61.18
Taper ratio . . . . .	0.565
Aspect ratio . . . . .	3.570
Sweep at 0.30 chord, deg . . . . .	35.0
Incidence at fuselage center line, deg . . . . .	3.0
Dihedral, deg . . . . .	-3.0
Geometric twist, deg . . . . .	0
Total aileron area (rearward of hinge line), sq ft . . . . .	9.8
Aileron travel (each), deg . . . . .	±15
Total flap area, sq ft . . . . .	12.58
Flap travel, deg . . . . .	50

## Horizontal tail:

Root airfoil section (normal to 0.30 chord) . . . . .	NACA 63-010
Tip airfoil section (normal to 0.30 chord) . . . . .	NACA 63-010
Area (including fuselage), sq ft . . . . .	39.9
Span, in. . . . .	143.6
Mean aerodynamic chord, in. . . . .	41.75
Root chord (parallel to plane of symmetry), in. . . . .	53.6
Tip chord (parallel to plane of symmetry), in. . . . .	26.8
Taper ratio . . . . .	0.50
Aspect ratio . . . . .	3.59
Sweep at 0.30 chord line, deg . . . . .	40.0
Dihedral, deg . . . . .	0
Elevator area, sq ft . . . . .	9.4
Elevator travel, deg	
Up . . . . .	25
Down . . . . .	15
Stabilizer travel, deg	
Leading edge up . . . . .	4
Leading edge down . . . . .	5



TABLE I.- PHYSICAL CHARACTERISTICS OF THE  
DOUGLAS D-558-II AIRPLANE - Concluded

Vertical tail:

Airfoil section (normal to 0.30 chord) . . . . .	NACA 63-010
Area, sq ft . . . . .	36.6
Height from fuselage center line, in. . . . .	98.0
Root chord (parallel to fuselage center line), in. . . . .	146.0
Rip chord (parallel to fuselage center line), in. . . . .	44.0
Sweep angle at 0.30 chord, deg . . . . .	49.0
Rudder area (rearward of hinge line), sq ft . . . . .	6.15
Rudder travel, deg . . . . .	±25

Fuselage:

Length, ft . . . . .	42.0
Maximum diameter, in. . . . .	60.0
Fineness ratio . . . . .	8.40
Speed-retarder area, sq ft . . . . .	5.25

Power plant:

Rocket . . . . . Reaction Motors, Inc.

Airplane weight (full rocket fuel), lb . . . . . 15,787

Airplane weight (no fuel), lb . . . . . 9,421

Center-of-gravity locations:

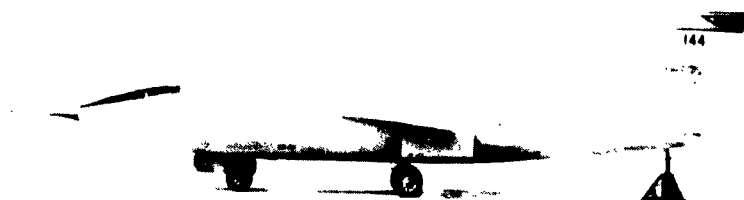
Full rocket fuel (gear up), percent mean aerodynamic chord . .	24.6
No fuel (gear up), percent mean aerodynamic chord . . . . .	27.3
No fuel (gear down), percent mean aerodynamic chord . . . . .	26.7





(a) Three-quarter rear view.

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(b) Side view.

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Figure 1.- Photographs of the Douglas D-558-II research airplane.

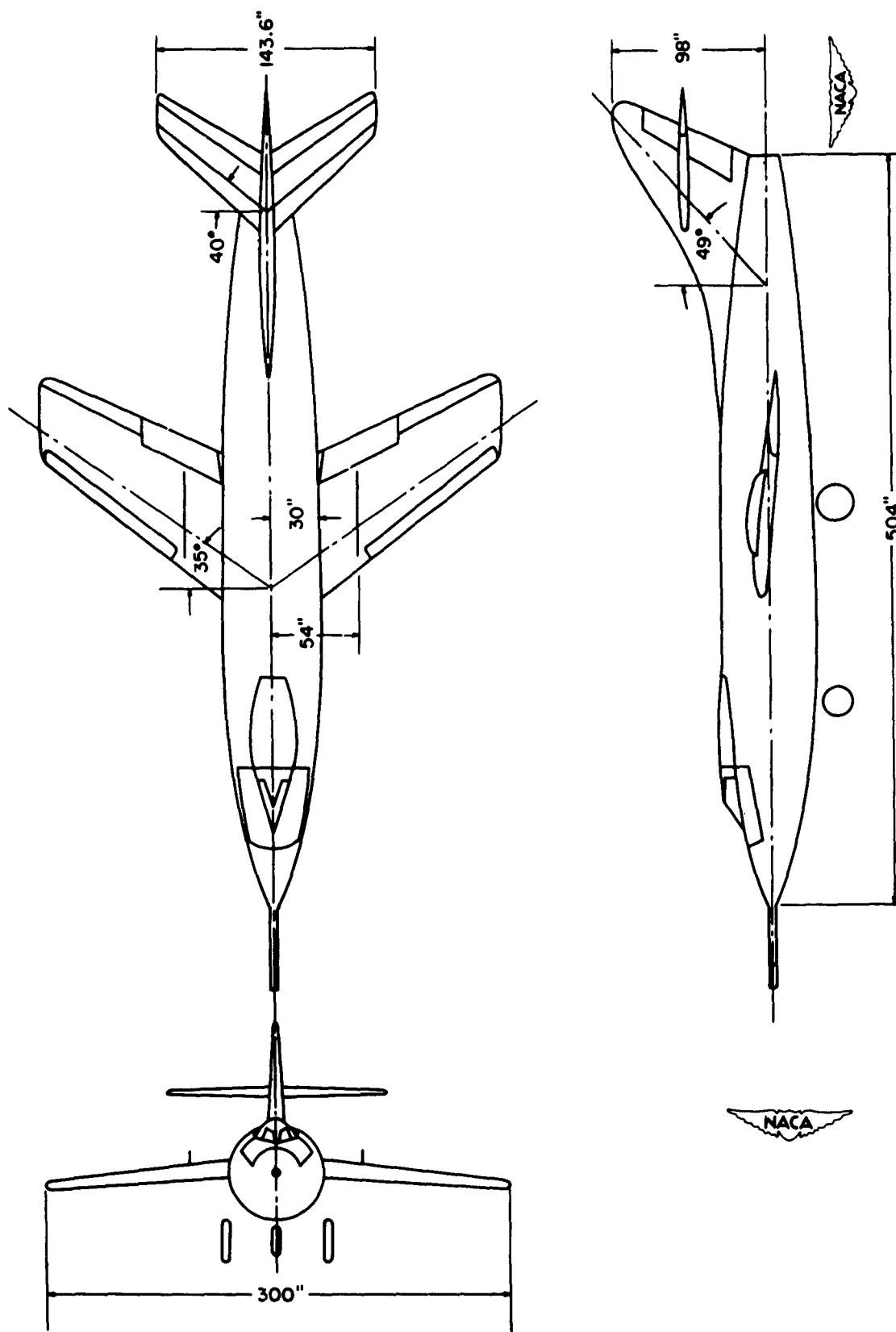


Figure 2.- Three-view drawing of the Douglas D-558-II research airplane.

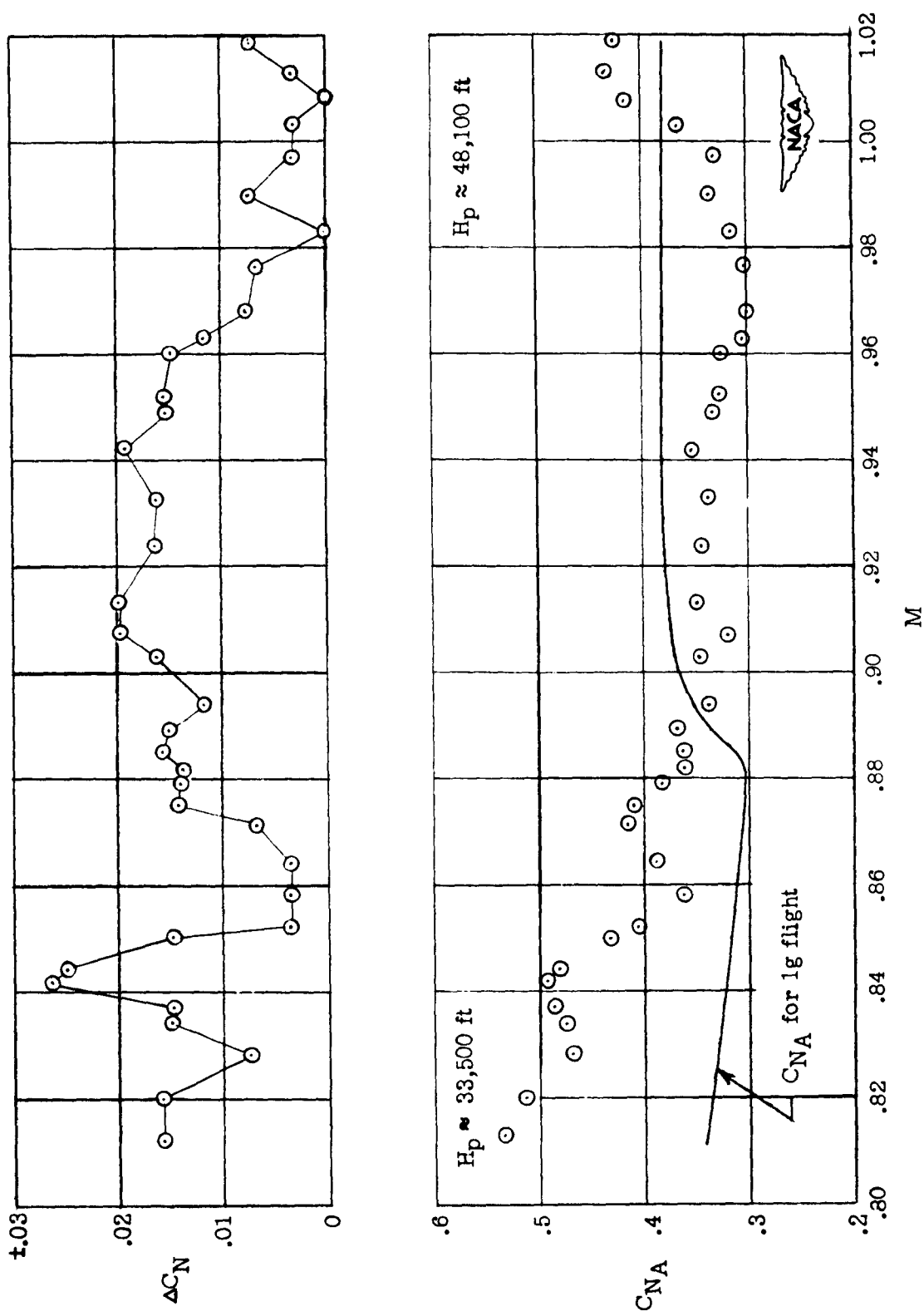
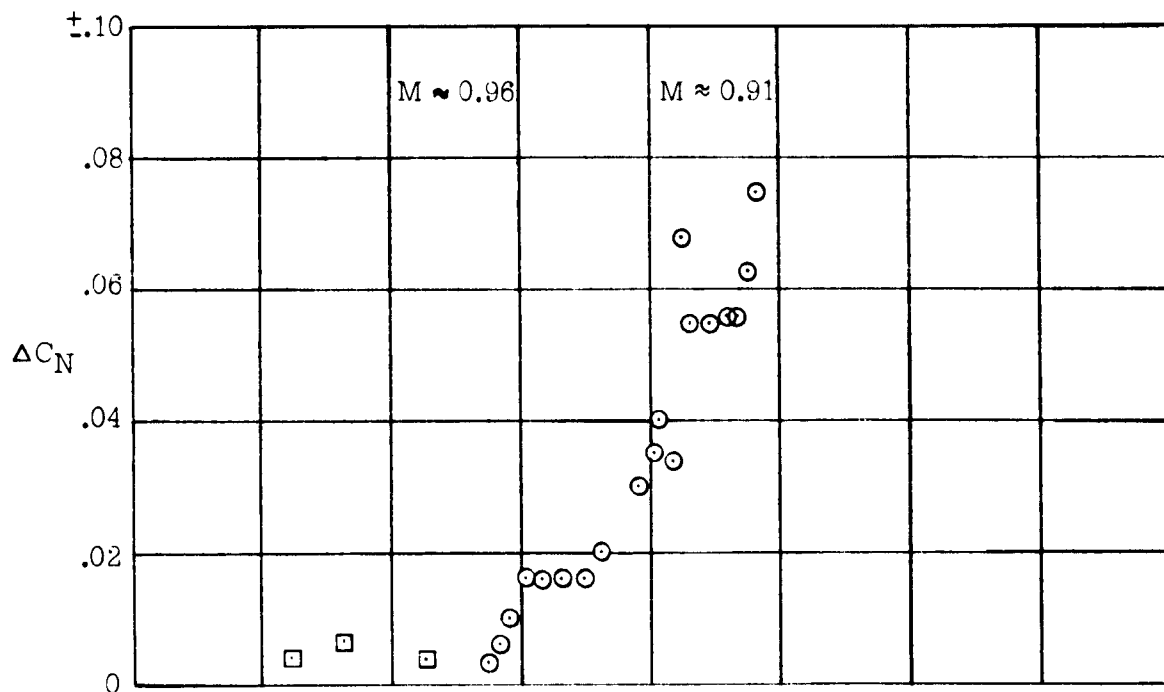
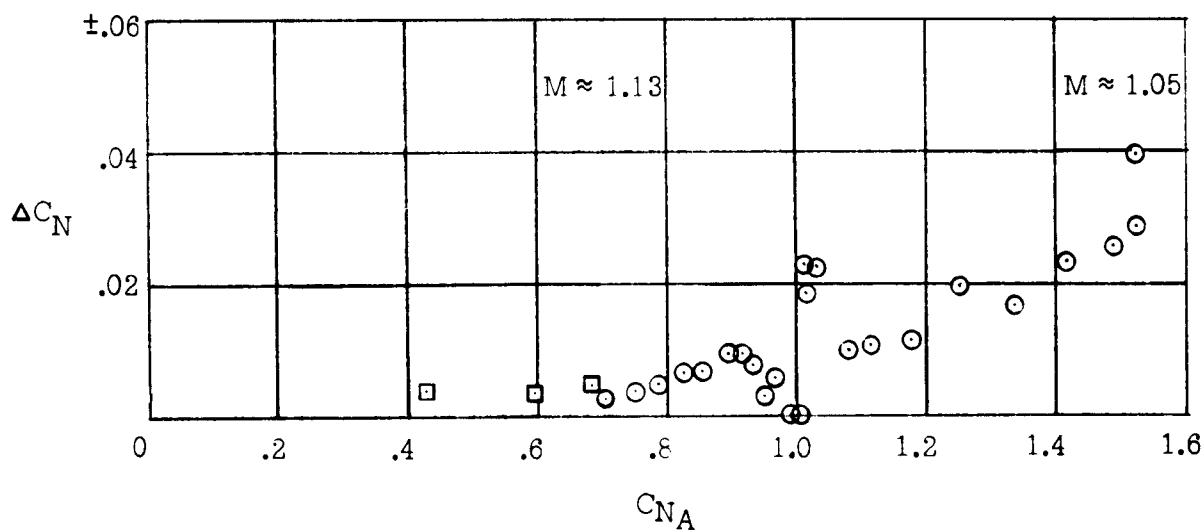


Figure 3.- Variation of airplane normal-force coefficient and buffet intensity with Mach number during a rocket-powered climb.

- Continuous data from one flight  
 □ Point data from other flights at comparative Mach numbers



(a) Subsonic.



(b) Supersonic.

Figure 4.- Typical variation of buffet intensity with lift during a subsonic and a supersonic turn.

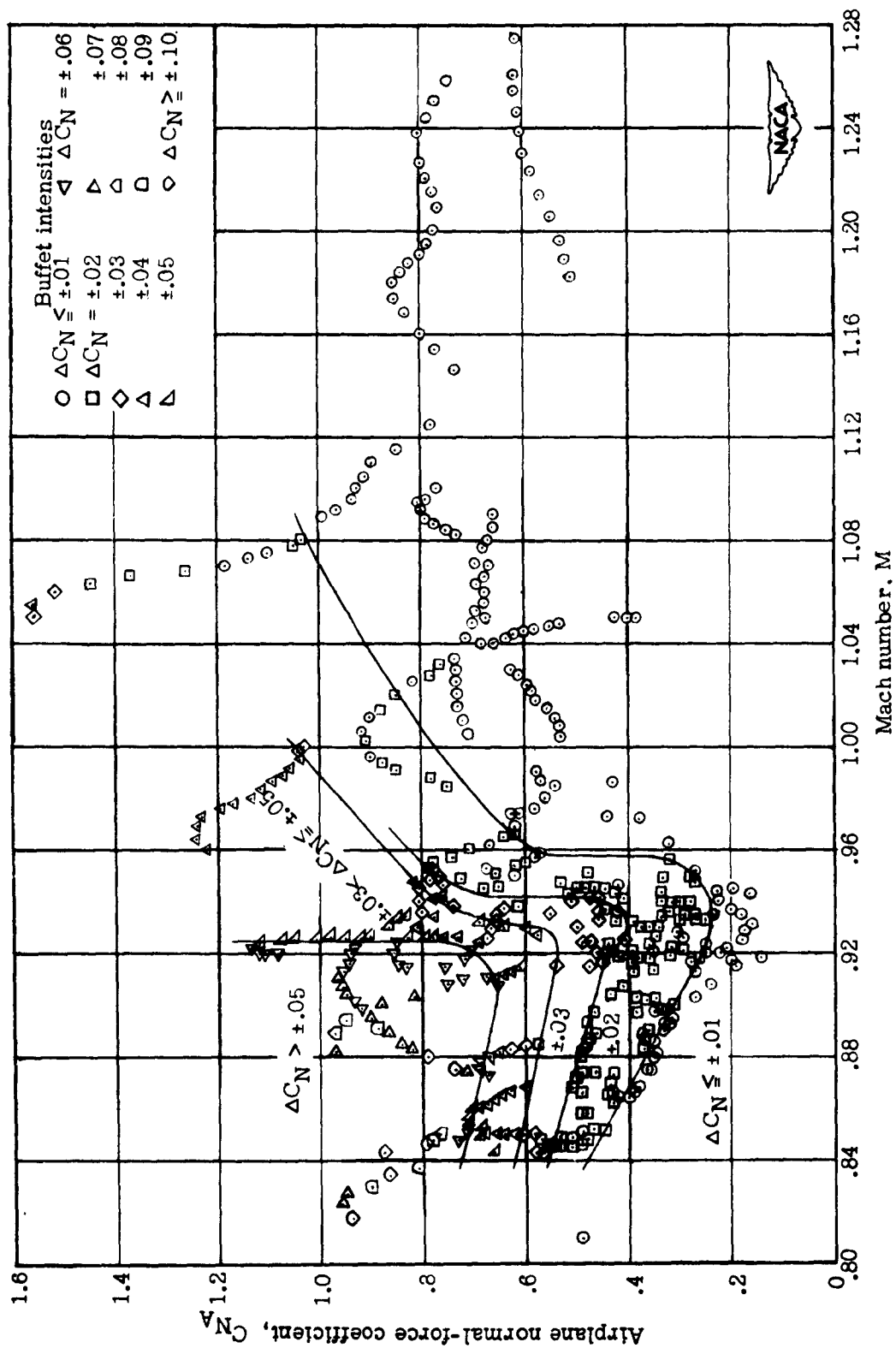


Figure 5.- The variation with Mach number and airplane normal-force coefficient of the intensity of buffeting experienced by the D-558-II airplane at transonic and supersonic Mach numbers.



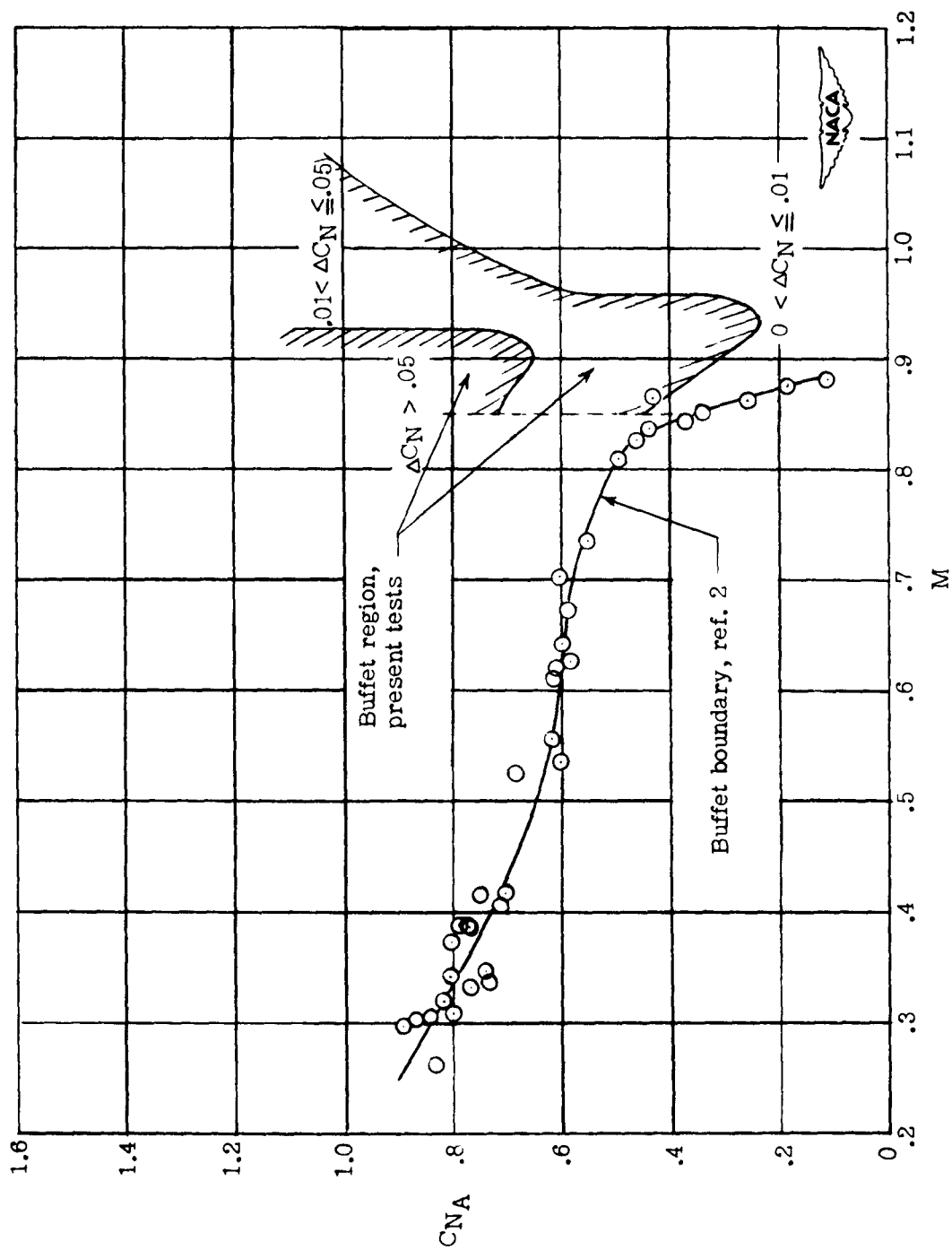


Figure 6.- Comparison of the region in which buffeting was experienced by the all-rocket airplane with the buffet boundary established with the jet-propelled airplane.

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Limited measurements have been made of the region in which buffeting has been experienced by the swept-wing Douglas D-558-II research airplane during flights to supersonic Mach numbers. Buffet intensities and frequencies are given.

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1. Mach Number Effects - Complete Wings (1. 2. 2. 6)
  2. Airplanes - Specific Types (1. 7. 1. 2)
  3. Flying Qualities (1. 8. 5)
  4. Vibration and Flutter (4. 2)
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